Remarks: General

The claims have been amended by (a) rewriting Claims 1, 3, 5, 10~13 and 16; (b) canceling Claim 2 without prejudice or disclaimer of the subject matter thereof; and (c) adding new Claims 18~23. No new matter is added by these amendments. New Claims 18~23 correspond to original Claims 4~9.

Corrected drawings are submitted for Figs. 3A, 3B, 4A, 4B, 5A, 5B, 6A, 6B, 7A, 7B, 8A, 8B, 9A, 9B, 10A, 10B, 11A and 11B. New drawings are submitted for Figs. 3C, 4C, 5C, 6C, 7C, 8C, 9C and 10C.

An associate power of attorney for the undersigned attorney is enclosed.

A petition under 37 CFR §1.136 for a three-month extension of time to respond the Examiner's action is enclosed, the fee for which should be charged to Deposit Account No. 04-1928 (E.I. du Pont de Nemours and Company).

The fees due by reason of the addition of Claims 18~23 are calculated on the attached sheet and may be charged to Deposit Account No. 04-1928. If the calculation on the attached sheet is in error, please charge or credit Deposit Account No. 04-1928 accordingly. If any fee other than or in addition to those mentioned above is required to authorize or obtain consideration of this response, please charge such fee to Deposit Account No. 04-1928 (E.I. du Pont de Nemours and Company).

Claims 1 and 3~23 are now active in the application. Applicant hereby requests reconsideration and further examination of the application in view of the reasons it has set forth below for allowance of the claims.

Remarks: Detailed Action

I.

The Examiner has objected to the disclosure because of various informalities. The informalities have been corrected, and Applicant therefore respectfully requests that the Examiner withdraw this objection to the disclosure.

II.

The Examiner has objected to the drawings because of various matters. These matters have been corrected, and Applicant therefore respectfully requests that the Examiner withdraw this objection to the drawings.

III.

The Examiner has rejected Claims 3~17 under 35 U.S.C. §112 as being indefinite. The matters identified by the Examiner have been addressed in claim amendments, and Applicant therefore respectfully requests that the Examiner withdraw the rejection of Claims 3~17 under 35 U.S.C. §112.

IV.

The Examiner has rejected Claim 1 under 35 U.S.C. 101 as claiming the same invention as Claim 10 of US 6,370,404. As Claim 1 has been amended so that it is no longer coextensive in scope with Claim 10 of the '404 patent, Applicant respectfully requests that the Examiner withdraw this rejection of Claim 1.

V.

The Examiner has rejected Claims 1~5, 7, 8, 10 and 12 under the judicially created doctrine of obviousness-type double patenting as being unpatentable over Claims 5 and 14~20 of US 6,108,569 in view of US 5,786,303 ("Mansour"). Claim 2 has been canceled. As a terminal disclaimer is being filed herewith, Applicant respectfully requests that the Examiner withdraw this rejection of Claims 1, 3~5, 7, 8, 10 and 12.

VI.

Applicant has reviewed the prior art made of record but not relied on, and submits that it is of no greater pertinence to the claims as amended than the patents mentioned above.

In view of the foregoing, Applicant submits that all of the Examiner's objections and rejections have been properly traversed, and that the pending claims are in condition for allowance, request for which is hereby respectfully made.

Respectfully submitted,

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Appendix A
Marked–Up Version of
Original Form of Deleted Paragraphs,
Showing Changes Thereto from Which
Replacement Paragraphs Are Derived

Page 1:
paragraph beginning at line 5 and ending at line 10

This application is a continuation of application Serial No. 09/592,466, filed 9 June 2000, now US 6,370,404 (which is incorporated as a part hereof as fully as if set forth at length herein), which is a continuation of application Serial No. 09/079,467, filed 15 May 1998, now US 6,108,569.

Page 6:
paragraph beginning at line 35 and ending at line 38

Figure 1 shows the prior art conventional spiral inductors, in which Figure 1a shows a prior-art square spiral inductor and Figure 1b shows a prior-art circular spiral inductor.

Page 7:
paragraphs beginning at line 9 and ending on page 9 at line 2

Figure 3 shows a first embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant rectangular spiral resonators with rounded corners, center tuning pads, and parallel lines input/output coupling circuits. Fig. 3a shows the front view thereof, with the lid of the case removed, and Fig. 3b and Fig. 3c show~~s~~, respectively, the ~~cross-section~~ end view and side view thereof.

Figure 4 shows a second embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant rectangular spiral resonators, transverse offset inter-resonator coupling adjustment, and inserted line input and output coupling circuits. Fig. 4a shows the front view thereof, with the lid of the case removed, and Fig. 4b and Fig. 4c show~~s~~, respectively, the ~~cross-section~~ end view and side view thereof.

Figure 5 shows a third embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant octagon spiral resonators, transverse offset inter-resonator coupling adjustment, and inserted line coupling input and output circuits. Fig. 5a shows the front view thereof, with the lid of the case removed, and Fig. 5b and Fig. 5c show~~s~~, respectively, the ~~cross-section~~ end view and side view thereof.

Figure 6 shows a fourth embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant circular spiral resonators, circular center tuning pads, and parallel lines input/output coupling circuits. Fig. 6a shows the front view thereof, with the lid of the case removed, and Fig. 6b and Fig. 6c show~~s~~, respectively, the ~~cross-section~~ end view and side view thereof.

Figure 7 shows a fifth embodiment of the present invention of a microstrip line 5-pole HTS mini-filter with four self-resonant rectangular spiral resonators, one symmetrical double spiral resonator, and inserted line input and output coupling circuits. Fig. 7a shows the front view thereof, with the lid of the case removed, and Fig. 7b and Fig. 7c show~~s~~, respectively, the ~~cross section~~ end view and side view thereof.

Figure 8 shows a first embodiment of the present invention of a microstrip line mini-multiplexer with two channels. Each channel comprises an 8-pole HTS mini-filter with self-resonant rectangular spiral resonators, and parallel lines input/output coupling circuits. The input circuit of the multiplexer is in the binary splitter form. Fig. 8a shows the front view thereof, with the lid of the case removed, and Fig. 8b and Fig. 8c show~~s~~, respectively, the ~~cross section~~ end view and side view thereof.

Figure 9 shows a second embodiment of the present invention of a microstrip line mini-multiplexer with four channels. Each channel comprises an 8-pole HTS mini-filter with self-resonant rectangular spiral resonators, and parallel lines input/output coupling circuits. The input circuit of the multiplexer is in the cascaded binary splitter form. Fig. 9a shows the front view thereof, with the lid of the case removed, and Fig. 9b and Fig. 9c show~~s~~, respectively, the ~~cross section~~ end view and side view thereof.

Figure 10 shows a third embodiment of the present invention of a microstrip line mini-multiplexer with four channels. Each channel comprises an 8-pole HTS mini-filter with self-resonant rectangular spiral resonators, and parallel lines input/output coupling circuits. The input circuit of the multiplexer is in the multi-branch line form. Fig. 10a shows the front view thereof, with the lid of the case removed, and Fig. 10b and Fig. 10c show~~s~~, respectively, the ~~cross section~~ end view and side view thereof.

Figure 11 shows an embodiment of the present invention of a strip line 4-pole HTS mini-filter with self-resonant rectangular spiral resonators with rounded corners, center tuning pads, and parallel lines input/output coupling circuits. Fig. 11a is a ~~cross-sectional~~side view of the mini-filter, and Fig. 11b is a plan view as seen along lines and arrows A-A of Fig. 11a.

Opposite

Page 12:
paragraph beginning at line 20 and ending on page 13 at line 2

The present invention solves the problems by utilizing the self-resonance of these spiral inductors instead of avoiding it. The self-resonance occurs when the operating frequency equals to the self-resonance frequency, f_s:

$$f_s = 1/\{2\pi[LC_p]^{1/2}\}$$

Here L is the inductance of the spiral, and C_p is the parasitic capacitance between adjacent turns. As mentioned above, for HTS filter design, it is desirable to reduce the size of the filter circuit which requires that the open area of the spiral (numeral 5 in Fig. ~~1 a~~ 1a and 1b), as well as the gap (numeral 2 in Fig. 1a and 1b) between the conductor lines be minimized. These measures not only reduce the size of the spiral resonator, but also eliminate the need for additional capacitance and the need for center connection. Moreover, these measures also confine most of the electromagnetic fields beneath the spiral resonator, hence solve the cross-talk problem caused by far reaching magnetic fields in the lumped conductor.

Page 14:
paragraphs beginning at line 33 and
ending on page 25 at line 23

Fig. 3 shows a first embodiment of the 4-pole HTS mini-filter circuit having four self-resonant spiral resonators (in this case having a rectangular configuration with rounded corners) as its frequency selecting element. Fig. 3a shows the top or front view of the filter~~, and~~ with the lid of the case removed, Fig. 3b shows ~~a cross-section~~an end view, and Fig. 3c shows a side view. In Figures 3a~~ and~~, 3b and 3c, numeral 30 is a dielectric substrate with a front side and a back side. The HTS filter mini-circuit is disposed on the front side of the substrate 30 as shown in Fig. 3a~~ and~~, 3b and 3c. The back side of the substrate 30 (which is seen in the ~~cross-sectional~~ views of Fig. 3b and Fig. 3c but is not seen in the view of Fig. 3a) is disposed with a blank HTS film 31 (see Fig. 3b and Fig. 3c) serving as the ground of the mini-filter circuit. A gold film 32 (see Fig. 3b and Fig. 3c) is disposed on top of HTS film 31 and functions as the contact to the mini-filter's case~~, which is not shown~~ 32a, shown in Figs. 3a, 3b and 3c. The case lid 32b is shown in Figs. 3b and 3c. In Fig. 3a, numerals 33, 34, 33a, and 34a are four self-resonant rectangular spiral resonators with rounded corners. The inter-resonator couplings are provided by the coupling gaps, 38, 38a, and 38b, between the adjacent resonators. The input coupling circuit is in a parallel lines form, which comprises an input line 35 and the coupling gap 39 between 35 and the first resonator 33. The output coupling circuit is in a parallel lines form, which comprises an output line 35a and the coupling gap 39a between 35a and the last resonator 33a. Two tuning pads 36, 36a are placed at the center of resonators 34 and 34a, respectively, for fine tuning the resonant frequency of the resonators 34 and 34a. Gold connecting pads 37 and 37a are disposed on the input and output line 35 and 35a, respectively, providing the connections to the mini-filter's input and output connectors~~, not~~ 37b and 37c, respectively, shown in Figs. 3a and 3c.

Fig. 4 shows a second embodiment of the 4-pole HTS mini-filter circuit having four self-resonant rectangular spiral resonators as its frequency selecting element, in which Fig. 4a shows the top or front view ~~and~~of the filter with the case removed, Fig. 4b shows ~~the cross section~~ an end view, and Fig. 4c shows a side view. Numeral 40 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on the front side of the substrate 40 as shown in Fig~~. 3a~~s. 4a, 4b and 4c. As indicated by the ~~cross section~~ views shown in Fig~~. 3b~~s. 4b and 4c, the back side of the substrate 40 is disposed with a blank HTS film 41 serving as the ground of the mini-filter circuit, and a gold film 42 is disposed on top of 41 serving as the contact to the mini-filter's case~~, which is not shown~~ 42a, shown in Figs. 4a~4c. The case lid 42b is shown in Figs. 4b and 4c. In Fig. 4a, numerals 43, 44, 43a, and 44a are the four self-resonant rectangular spiral resonators. The inter-resonator couplings are provided by the coupling gaps 49, 49a, 49b between adjacent resonators. In this particular case, the inter-resonator coupling strength is adjusted by changing the gap width between the adjacent resonators, as well as by shifting the resonator's location in the transverse direction for the fine adjustment. The input coupling circuit is in the inserted line form, which comprises an input line 45 with its extended narrower line 46 inserted into the split spiral line of the first resonator 43 with a coupling gap 47 between them. The output coupling circuit is in the inserted line form, which comprises an output line 45a with its extended narrower line 46a inserted into the split spiral line of the last resonator 43a with a coupling gap 47a between them. Gold connecting pads 48 and 48a are disposed on the input and output lines 45 and 45a, respectively, providing the connections to the mini-filter's input and output connectors~~, not shown~~48b and 48c, respectively, shown in Figs. 4a and 4c.

Fig. 5 shows a third embodiment of the 4-pole HTS mini-filter circuit having self-resonant four octagon spiral resonators as its frequency selecting element, in which Fig. 5a shows the top or front view~~, and~~ with the lid of the case removed, Fig. 5b shows ~~the cross~~

~~section~~an end view, and Fig. 5c shows a side view. Numeral 50 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on the front side of the substrate 50 as shown in Figs. 5a~5c. As indicated by the ~~cross-section~~ views shown in Fig. 5b and Fig. 5c, the back side of the substrate 50 is disposed with a blank HTS film 51 serving as the ground of the mini-filter circuit, and a gold film 52 is disposed on top of blank HTS film 51 serving as the contact to the mini-filter's case~~, not shown~~ 52a, shown in Figs. 5a~5c. The case lid 52b is shown in Figs. 5b and 5c. In Fig. 5a, numerals 53, 54, 53a, and 54a are the four self-resonant octagon spiral resonators. The inter-resonator couplings are provided by the coupling gaps 59, 59a, 59b, between adjacent resonators. In this particular case, the inter-resonator coupling strength is adjusted by changing the gap width between the adjacent resonators, as well as by shifting the resonator's location in the transverse direction for the fine adjustment. The input coupling circuit is in the inserted line form, which comprises an input line 55 with its extended line 56 inserted into the split spiral line of the first resonator 53 with a coupling gap 57 between them. The output coupling circuit is in the inserted line form, which comprises an output line 55a with its extended line 56a inserted into the split spiral line of the last resonator 53a with a coupling gap 57a between them. Gold connecting pads 58 and 58a are disposed on the input and output lines 55 and 55a, respectively, providing the connections to the mini-filter's input and output connectors~~, not shown~~ 58b and 58c, respectively, shown in Figs. 5a and 5c.

Fig. 6 shows a fourth embodiment of the 4-pole HTS mini-filter circuit having four self-resonant circular spiral resonators as its frequency selecting element, in which Fig. 6a shows the circuit top or front view with the lid of the case removed, ~~and~~ Fig. 6b shows the ~~cross section~~ end view, and Fig. 6c shows the side view. Numeral 60 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on the front side of the substrate 60 as shown in Figs. 6a~6c. As indicated by the ~~cross section~~ end view shown in Fig. 6b and the side view shown in Fig. 6c, the back side of

the substrate 60 is disposed with a blank HTS film 61 serving as the ground of the mini-filter circuit, and a gold film 62 is disposed on top of blank HTS film 61 serving as the contact to the mini-filter's case~~,~~ ~~not shown~~ 62a, shown in Figs. 6a~6c. The case lid 62b is shown in Figs. 6b and 6c. In Fig. 6a, numerals 63, 64, 63a, and 64a are the four self-resonant circular spiral resonators. The inter-resonator couplings are provided by the coupling gaps 63b, 63c, 63d, between adjacent resonators. The input coupling circuit is in the parallel line form, which comprises an input line 66 and an extended line 67, the input coupling is provided by the gap 69 between 67 and the first resonator 63. The output coupling circuit is in the parallel line form, which comprises an output line 66a and an extended line 67a, the output coupling is provided by the gap 69a between 67 and the first resonator 63. Two tuning pads 65, 65a are placed at the center of resonators 63 and 63a, respectively, for fine tuning the resonant frequency of the resonators 63 and 63a. Gold connecting pads 68 and 68a are disposed on the input and output lines 66 and 66a, respectively, providing the connections to the mini-filter's input and output connectors~~, not shown in the figures~~68b and 68c, respectively, shown in Figs. 6a and 6c.

Fig. 7 shows one embodiment of a 5-pole HTS mini-filter circuit having five self-resonant rectangular spiral resonators as its frequency selecting element, in which Fig. 7a shows the circuit top or front view~~,~~ ~~and~~ with the lid of the case removed, Fig. 7b shows the ~~cross-section~~ end view, and Fig. 7c shows the side view. Numeral 70 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on the front side of the substrate 70 as shown in Figs. 7a~7c. As indicated by the ~~cross-section~~ end view shown in Fig. 7b and the side view shown in Fig. 7c, the back side of the substrate 70 is disposed with a blank HTS film 71 serving as the ground of the mini-filter circuit, and a gold film 72 is disposed on top of blank HTS film 71 serving as the contact to the mini-filter's case~~,~~ ~~which is not shown~~ 72a, shown in Figs. 7a~7c. The case lid 72b is shown in Figs. 7b and 7c. In Fig. 7a, numerals 73, 74, 73a, and 74a are the four self-resonant rectangular single spiral resonators,

numeral 75 is a self-resonant rectangular double spiral resonator, which is centrally located and thus serves as the middle resonator. The use of double spiral resonator 75 at the middle of the 5-pole filter is to make the circuit geometry symmetrical with respect to the input and the output. This approach is also suitable for any symmetrical mini-filter with odd number poles. The inter-resonator couplings are provided by the coupling gaps 75a, 75b, 75c, 75d, between adjacent resonators. In this particular case, the inter-resonator coupling strength is adjusted by changing the gap width between the adjacent resonators. The input coupling circuit is in an inserted line form, which comprises an input line 76 with its extended narrower line 77 inserted into the split spiral line of first resonator 73 with a coupling gap 78 between them. The output coupling circuit is in a inserted line form, which comprises an output line 76a with its extended narrower line 77a inserted into the split spiral line of last resonator 73a with a coupling gap 78a between them. Gold connecting pads 79 and 79a are disposed on the input and output lines 76 and 76a, respectively, providing the connections to the mini-filter's input and output connectors~~, not shown~~ 79b and 79c, respectively, shown in Figs. 7a and 7c.

Fig. 8 shows a 2-channel mini-multiplexer, each channel has a 8-pole HTS mini-filter 83, 83a (see Fig. 8a), respectively, with eight rectangular self-resonant spiral resonators. Fig. 8a shows the top or front view ~~and~~ with the lid of the case removed, Fig. 8b shows the ~~cross section~~ end view, and Fig. 8c shows the side view. Numeral 80 is a dielectric substrate with a front side and a back side. The HTS mini-multiplexer circuit is disposed on the front side of substrate 80 as shown in Figs. 8a~8c. As indicated by the ~~cross section~~ end view shown in Fig. 8b and the side view shown in Fig. 8c, the back side of the substrate 80 is disposed with a blank HTS film 81 serving as the ground of the mini-multiplexer circuit, and a gold film 82 is disposed on top of blank HTS film 81 serving as the contact to the mini-multiplexer's case~~, which is not shown~~ 82a, shown in Figs. 8a~8c. The case lid 82b is shown in Figs. 8b and 8c. The frequency bands of mini-filters 83 and 83a are slightly different and without overlapping

to form two channels. ~~T~~As shown in Fig. 8a, the input coupling circuits of mini-filters 83 and 83a are in the parallel lines form, which comprise input lines 84 and 84a and the gaps 84b, 84c, respectively, between input lines 84 and 84a and the first spiral resonator of filters 83 and 83a, respectively. A distribution network in a single binary splitter form serves as the input of the multiplexer, which comprises the common input line 86, a T-junction 87, and branch lines 85 and 85a, with one end of each of the branch lines 85 and 85a commonly connected to T-junction 87, and the other end thereof connected to coupling lines 84 and 84a, respectively. The dimensions of coupling lines 84 and 84a, branch lines 85 and 85a, common input line 86 and T-junction 87 are selected in such a way to provide the input impedance matching of the mini-multiplexer over the frequency range covering the two frequency bands of filters 83 and 83a. The output coupling circuits of filters 83 and 83a are in the parallel lines form, which comprise the output lines 87a and 87b, and the gap 87c, 87d, respectively, between them and the last resonator of filters 83 or 83a. Output lines 87a and 87b also serve as the output lines for the two channels of the mini-multiplexer. Gold connecting pads 88, 88a and 88b are disposed on the input line 86, and output lines 87a and 87b, respectively, providing the connections to the mini-multiplexer's ~~connectors, not shown~~input connector 89 and the two output connectors 89a and 89b, shown in Figure 8a.

It should be understood that the form of the self-resonant spiral resonators in the mini-multiplexer is not restricted to the rectangular form illustrated in Fig. 8, but rather they can be of any configuration such as shown in Figs. 2a-2d or combinations thereof. Further it is to be understood that the form of the input and output coupling circuits of the mini-filters in the mini-multiplexer is not restricted to the parallel line form shown in Fig. 8, but instead other line forms may be used, such as the inserted line form or combinations of inserted line form and parallel line form.

Fig. 9 shows a second embodiment of the 4-channel mini-multiplexer, each channel having an 8-pole HTS mini-filter with eight

self-resonant rectangular spiral resonators, in which Fig. 9a show~~n~~s the top or front view ~~and~~with the lid of the case removed, Fig. 9b shows the ~~cross section~~ end view, and Fig. 9c shows the side view. Numeral 90 is a dielectric substrate with a front side and a back side. The HTS mini-multiplexer circuit is disposed on the front side of substrate 90 as shown in Figs. 9a~9c. As indicated by the ~~cross section~~ end view shown in Fig. 9b and the side view shown in Fig. 9c, the back side of the substrate 90 is disposed with a blank HTS film 91 serving as the ground of the mini-multiplexer circuit, and a gold film 92 is disposed on top of blank HTS film 91 serving as the contact to the mini-multiplexers case~~, not shown~~ 98 shown in Figs. 9a~9c. The case lid 99 is shown in Figs. 9b and 9c. ~~N~~In Fig. 9a, numerals 93 and 93a are used to designate two 2-channel mini-multiplexers similar to that shown in Fig. 8. The frequency bands of mini-multiplexers 93 and 93a are slightly different and without overlapping. ~~T~~As shown in Fig. 9a, the distribution network at the input of the 4-channel mini-multiplexer is in a 2-stage cascaded binary splitter form. The first stage comprises a common input line 95, a T-junction 96 and two branch lines 94 and 94a, with one end of each of the branch lines 94 and 94a commonly connected to T-junction 96, and the other end thereof connected to the input lines 94b and 94c, respectively, of the second stage. The second stage comprises two binary splitters, which actually are the input binary splitters of the two 2-channel mini-multiplexers 93 and 93a, and comprise input lines 94b and 94c; T-junctions 94d and 94e; branch lines 94f, 94g, 94h and 94i; and input lines 94j, 94k, 94l and 94m, as shown in Fig. 9a. The dimensions of mini-multiplexers 93 and 93a, branch lines 94 and 94a, input lines 94b and 94c, T-junctions 94d and 94e, branch lines 94f, 94g, 94h and 94i, input lines 94j, 94k, 94l and 94m, common input line 95 and T-junction 96 are selected in such a way to provide the input impedance matching of the mini-multiplexer over the frequency range covering the four frequency bands of the 4-channel mini-multiplexer. The output circuits of the 4-channel mini-multiplexer comprise the two 2-channel mini-multiplexers' output lines: 97, 97a, 97b, 97c, which serve as the four output lines for the 4-channel mini-multiplexer as shown in Fig. 9a.

Fig. 10 shows a third embodiment of the 4-channel mini-multiplexer, each channel comprising an 8-pole HTS mini-filter 103, 103a, 103b, 103c (see Fig. 10a), with eight self-resonant rectangular spiral resonators. Fig. 10a shows the top or front view ~~and~~with the lid of the case removed, Fig. 10b shows the ~~cross-section~~ end view, and Fig. 10c shows the side view. Numeral 100 is a dielectric substrate with a front side and a back side. The HTS mini-multiplexer circuit is disposed on the front side of substrate 100 as shown in Figs. 10a~10c. As indicated by the ~~cross-section~~ end view shown in Fig. 10b and the side view shown in Fig. 10c, the back side of the substrate 100 is disposed with a blank HTS film 101 serving as the ground of the mini-multiplexer circuit, and a gold film 102 is disposed on top of blank HTS film 101 serving as the contact to the mini-multiplexer's case~~,~~ ~~which is not shown~~ 109, shown in Figs. 10a~10c. The case lid 109a is shown in Figs. 10b and 10c. The frequency bands of filters 103, 103a, 103b, and 103c are slightly different and without overlapping to form four channels. ~~T~~As shown in Fig. 10a, the distribution network at the input of the 4-channel mini-multiplexer is in a matched branch lines form, which comprises a common input line 106, a matching section 105, line sections 104, 104a, 104b, 104c, and five junctions: 107, 107a, 107b, 107c and 107d. The dimensions of line sections 104, 104a, 104b and 104c, matching section 105, common input line 106, and junctions 107, 107a, 107b, 107c and 107d, are selected in such a way to provide the input impedance matching of the mini-multiplexer over the frequency range covering the four frequency bands of the 4-channel mini-multiplexer. The output circuits of the 4-channel mini-multiplexer comprise the four mini-filter's output lines: 108, 108a, 108b, 108c, which serve as the four output lines for the 4-channel mini-multiplexer as shown in Fig. 10a.

Fig. 11 shows an example of a 4-pole HTS filter in the strip line form with four rectangular self-resonant spiral resonators with rounded corners as its frequency selecting element. Fig. 11a is a ~~cross sectional~~ side view of the filter and Fig. 11b is a view as seen along lines and arrows A-A of Fig. 11a. Numeral 110 is a dielectric

substrate with a front side and a back side. The HTS filter circuit 113 is disposed on the front side of substrate 110 as seen in Fig. 11b. As shown in Fig. 11a, a first blank HTS film 111 is disposed on the back side of substrate 110 serving as one of the two ground planes for the strip line, a first gold film 112 is disposed on top of first blank HTS film 111 serving as the contact to the filter's case~~, which is not shown in the figures~~ 118, shown in Figs. 11a and 11b. Numeral 110a is a dielectric superstrate with a front side and a back side. As shown in Fig. 11a, a second blank HTS film 111a is disposed on the back side of superstrate 110a serving as one of the two ground planes for the strip line, a second gold film 112a is disposed on top of second blank HTS film 111a serving as the contact to the filter's case ~~(not shown)~~lid 119, shown in Fig. 11a. As is also shown in Fig. 11a, superstrate 110a is smaller in size than substrate 110, whereby the first end (e.g., microstrip line 115 and gold contact pad 116) of the input coupling circuit and the first end (e.g., microstrip line 115a and gold contact pad 116a) of the output coupling circuit are each located outside the dimensions of superstrate 110a, that is, they are not covered by superstrate 110a. Although not shown, it is understood that the mirror image of HTS filter circuit 113 could also be disposed on the front side of superstrate 110a and the two mirror image circuits aligned. As shown in Fig. 11b, the input and output strip lines 114 and 114a are extended into broader microstrip lines 115 and 115a, respectively, on the substrate 110. Gold contact pads 116 and 116a are disposed on microstrip lines 115 and 115a, respectively (also seen in Fig. 11a), providing the connections to the filter ~~case (not shown)~~input and output connectors 117 and 117a , respectively, shown in Figs. 11a and 11b. The line width of output strip lines 114 and 114a, and microstrip lines 115 and 115a, are selected in such a way to achieve the impedance matching at the input and the output.

In all of the embodiments described above, it is preferred that the high temperature superconductor is selected from the group consisting of $YBa_2Cu_3O_7$, $Tl_2Ba_2CaCu_2O_8$, $TlBa_2Ca_2Cu_3O_9$, $(TlPb)Sr_2CaCu_2O_7$ and $(TlPb)Sr_2Ca_2Cu_3O_9$. It is also preferred that

the substrate and superstrate are independently selected from the group consisting of $LaAlO_3$, MgO, $LiNbO_3$, sapphire and quartz.

EXAMPLE

A mini-filter having the circuit layout shown in Figure 12 was prepared. It is a 3-pole 0.16 GHz bandwidth centered at 5.94 GHz mini filter in the microstrip line form. It consists of three rectangular self-resonant spiral resonators, 121, 121a, 121b, each having a tuning pad at the center, 122, 122a, 122b, parallel lines input and output coupling circuits, 123, 123a. The substrate 120 is made of $LaAlO_3$ with dimensions of 5.250 mm x 3.000 mm x 0.508 mm. The HTS thin film is $Tl_2Ba_2CaCu_2O_8$. The filter was fabricated, and tested at 77 K. The measured S-parameter data are shown in Fig. 13, in which Fig. 13a shows S_{11} versus frequency data, Fig. 13b shows S_{12} versus frequency data, Fig. 13c shows S_{21} versus frequency data, Fig. 13d shows S_{22} versus frequency data. S_{11} is the magnitude of the reflection coefficient from the input port; S_{21} is the magnitude of the transmitting coefficient from the input port to the output port; S_{22} is the magnitude of the reflection coefficient from the output port; and S_{12} is the magnitude of the transmitting coefficient from the output port to the input port. The results show that the center frequency is about 5.95 GHz and the band width is about 170 MHz. The return loss is about 12 dB (see, e.g., Fig. 13a, wherein the scale along the ordinate axis is 5 dB per division). Reference to Fig. 13b or 13c shows there is essentially zero insertion loss. The measured data were in agreement with the computer simulated data very well, the center frequency difference was less than 0.1%. Fig 13a

The mini-filter was also tested under two different conditions. That is, it was tested in the air with a relative dielectric constant of approximately 1.00, and also was tested in liquid nitrogen with a relative dielectric constant of approximately 1.46. Fig. 14 shows the S_{21} versus frequency data, in which 131 is for the air data and 132 is for the liquid nitrogen data. The results indicate a frequency shift of only 0.04 GHz corresponding to 0.67% of the center frequency. The

very small frequency shift is an indirect indication of most electromagnetic fields confinement beneath the spiral resonators.

The filter was also tested under power from 0.01 watt up to 0.2 watt cw rf power without measurable changes in its S_{21}. The Third Order Intercept (TOI) test is an indication of the non-linearity of the filter. The higher the intercept, the higher the power handling capability of the filter. Test data are shown in Fig. 15 in a log-log scale, in which line 141 is the best fit straight line with a slope of 1 for the sum of two fundamental frequencies, line 142 is the best fit straight line with a slope of 3 for the third order intermadulation. The intercept of these two lines gives a TOI of 39.5 dBm, which is a high value and indicates the power handling capability of the filter. Both the power and the TOI test data are in line with similar conventional HTS filters with the same line width and ten times larger size. These test results confirmed that the one order of magnitude reduction of size does not degrade the mini-filter's performance compared to the conventional design.

Appendix B
Clean Form of Replacement Paragraphs
Containing Changes as Incorporated into
Original Form

Page 1:
paragraph beginning at line 5 and ending at line 10

A1

This application is a continuation of application Serial No. 09/592,466, filed 9 June 2000, now US 6,370,404 (which is incorporated as a part hereof as fully as if set forth at length herein), which is a continuation of application Serial No. 09/079,467, filed 15 May 1998, now US 6,108,569.

Page 6:
paragraph beginning at line 35 and ending at line 38

A2

Figure 1 shows the prior art conventional spiral inductors, in which Figure 1a shows a prior-art square spiral inductor and Figure 1b shows a prior-art circular spiral inductor.

Page 7:
paragraphs beginning at line 9 and ending on page 9 at line 2

Figure 3 shows a first embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant rectangular spiral resonators with rounded corners, center tuning pads, and parallel lines input/output coupling circuits. Fig. 3a shows the front view thereof, with the lid of the case removed, and Fig. 3b and Fig. 3c show, respectively, the end view and side view thereof.

Figure 4 shows a second embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant rectangular spiral resonators, transverse offset inter-resonator coupling adjustment, and inserted line input and output coupling circuits. Fig. 4a shows the front view thereof, with the lid of the case removed, and Fig. 4b and Fig. 4c show, respectively, the end view and side view thereof.

Figure 5 shows a third embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant octagon spiral resonators, transverse offset inter-resonator coupling adjustment, and inserted line coupling input and output circuits. Fig. 5a shows the front view thereof, with the lid of the case removed, and Fig. 5b and Fig. 5c show, respectively, the end view and side view thereof.

Figure 6 shows a fourth embodiment of the present invention of a microstrip line 4-pole HTS mini-filter with self-resonant circular spiral resonators, circular center tuning pads, and parallel lines input/output coupling circuits. Fig. 6a shows the front view thereof, with the lid of the case removed, and Fig. 6b and Fig. 6c show, respectively, the end view and side view thereof.

Figure 7 shows a fifth embodiment of the present invention of a microstrip line 5-pole HTS mini-filter with four self-resonant rectangular spiral resonators, one symmetrical double spiral resonator, and inserted line input and output coupling circuits. Fig. 7a shows the front view thereof, with the lid of the case removed, and Fig. 7b and Fig. 7c show, respectively, the end view and side view thereof.

A3 (continued)

Figure 8 shows a first embodiment of the present invention of a microstrip line mini-multiplexer with two channels. Each channel comprises an 8-pole HTS mini-filter with self-resonant rectangular spiral resonators, and parallel lines input/output coupling circuits. The input circuit of the multiplexer is in the binary splitter form. Fig. 8a shows the front view thereof, with the lid of the case removed, and Fig. 8b and Fig. 8c show, respectively, the end view and side view thereof.

Figure 9 shows a second embodiment of the present invention of a microstrip line mini-multiplexer with four channels. Each channel comprises an 8-pole HTS mini-filter with self-resonant rectangular spiral resonators, and parallel lines input/output coupling circuits. The input circuit of the multiplexer is in the cascaded binary splitter form. Fig. 9a shows the front view thereof, with the lid of the case removed, and Fig. 9b and Fig. 9c show, respectively, the end view and side view thereof.

Figure 10 shows a third embodiment of the present invention of a microstrip line mini-multiplexer with four channels. Each channel comprises an 8-pole HTS mini-filter with self-resonant rectangular spiral resonators, and parallel lines input/output coupling circuits. The input circuit of the multiplexer is in the multi-branch line form. Fig. 10a shows the front view thereof, with the lid of the case removed, and Fig. 10b and Fig. 10c show, respectively, the end view and side view thereof.

a3 (concluded)

Figure 11 shows an embodiment of the present invention of a strip line 4-pole HTS mini-filter with self-resonant rectangular spiral resonators with rounded corners, center tuning pads, and parallel lines input/output coupling circuits. Fig. 11a is a side view of the mini-filter, and Fig. 11b is a plan view as seen along lines and arrows A-A of Fig. 11a.

Page 12:
paragraph beginning at line 20 and ending on page 13 at line 2

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a4

The present invention solves the problems by utilizing the self-resonance of these spiral inductors instead of avoiding it. The self-resonance occurs when the operating frequency equals to the self-resonance frequency, f_S:

$$f_S = 1/\{2\pi[LC_p]^{1/2}\}$$

Here L is the inductance of the spiral, and C_p is the parasitic capacitance between adjacent turns. As mentioned above, for HTS filter design, it is desirable to reduce the size of the filter circuit which requires that the open area of the spiral (numeral 5 in Fig. 1a and 1b), as well as the gap (numeral 2 in Fig. 1a and 1b) between the conductor lines be minimized. These measures not only reduce the size of the spiral resonator, but also eliminate the need for additional capacitance and the need for center connection. Moreover, these measures also confine most of the electromagnetic fields beneath the spiral resonator, hence solve the cross-talk problem caused by far reaching magnetic fields in the lumped conductor.

Page 14:
paragraphs beginning at line 33 and ending on page 25 at line 23

P5

Fig. 3 shows a first embodiment of the 4-pole HTS mini-filter circuit having four self-resonant spiral resonators (in this case having a rectangular configuration with rounded corners) as its frequency selecting element. Fig. 3a shows the top or front view of the filter with the lid of the case removed, Fig. 3b shows an end view, and Fig. 3c shows a side view. In Figures 3a, 3b and 3c, numeral 30 is a dielectric substrate with a front side and a back side. The HTS filter mini-circuit is disposed on the front side of the substrate 30 as shown in Fig. 3a, 3b and 3c. The back side of the substrate 30 (which is seen in the views of Fig. 3b and Fig. 3c but is not seen in the view of Fig. 3a) is disposed with a blank HTS film 31 (see Fig. 3b and Fig. 3c) serving as the ground of the mini-filter circuit. A gold film 32 (see Fig. 3b and Fig. 3c) is disposed on top of HTS film 31 and functions as the contact to the mini-filter's case 32a, shown in Figs. 3a, 3b and 3c. The case lid 32b is shown in Figs. 3b and 3c. In Fig. 3a, numerals 33, 34, 33a, and 34a are four self-resonant rectangular spiral resonators with rounded corners. The inter-resonator couplings are provided by the coupling gaps, 38, 38a, and 38b, between the adjacent resonators. The input coupling circuit is in a parallel lines form, which comprises an input line 35 and the coupling gap 39 between 35 and the first resonator 33. The output coupling circuit is in a parallel lines form, which comprises an output line 35a and the coupling gap 39a between 35a and the last resonator 33a. Two tuning pads 36, 36a are placed at the center of resonators 34 and 34a, respectively, for fine tuning the resonant frequency of the resonators 34 and 34a. Gold connecting pads 37 and 37a are disposed on the input and output line 35 and 35a, respectively, providing the connections to the mini-filter's input and output connectors 37b and 37c, respectively, shown in Figs. 3a and 3c.

A5 (continued)

Fig. 4 shows a second embodiment of the 4-pole HTS mini-filter circuit having four self-resonant rectangular spiral resonators as its frequency selecting element, in which Fig. 4a shows the top or front view of the filter with the case removed, Fig. 4b shows an end view, and Fig. 4c shows a side view. Numeral 40 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on the front side of the substrate 40 as shown in Figs. 4a, 4b and 4c. As indicated by the views shown in Figs. 4b and 4c, the back side of the substrate 40 is disposed with a blank HTS film 41 serving as the ground of the mini-filter circuit, and a gold film 42 is disposed on top of 41 serving as the contact to the mini-filter's case 42a, shown in Figs. 4a~4c. The case lid 42b is shown in Figs. 4b and 4c. In Fig. 4a, numerals 43, 44, 43a, and 44a are the four self-resonant rectangular spiral resonators. The inter-resonator couplings are provided by the coupling gaps 49, 49a, 49b between adjacent resonators. In this particular case, the inter-resonator coupling strength is adjusted by changing the gap width between the adjacent resonators, as well as by shifting the resonator's location in the transverse direction for the fine adjustment. The input coupling circuit is in the inserted line form, which comprises an input line 45 with its extended narrower line 46 inserted into the split spiral line of the first resonator 43 with a coupling gap 47 between them. The output coupling circuit is in the inserted line form, which comprises an output line 45a with its extended narrower line 46a inserted into the split spiral line of the last resonator 43a with a coupling gap 47a between them. Gold connecting pads 48 and 48a are disposed on the input and output lines 45 and 45a, respectively, providing the connections to the mini-filter's input and output connectors48b and 48c, respectively, shown in Figs. 4a and 4c.

Fig. 5 shows a third embodiment of the 4-pole HTS mini-filter circuit having self-resonant four octagon spiral resonators as its frequency selecting element, in which Fig. 5a shows the top or front view with the lid of the case removed, Fig. 5b shows an end view, and Fig. 5c shows a side view. Numeral 50 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on

A5 (continued)

the front side of the substrate 50 as shown in Figs. 5a~5c. As indicated by the views shown in Fig. 5b and Fig. 5c, the back side of the substrate 50 is disposed with a blank HTS film 51 serving as the ground of the mini-filter circuit, and a gold film 52 is disposed on top of blank HTS film 51 serving as the contact to the mini-filter's case 52a, shown in Figs. 5a~5c. The case lid 52b is shown in Figs. 5b and 5c. In Fig. 5a, numerals 53, 54, 53a, and 54a are the four self-resonant octagon spiral resonators. The inter-resonator couplings are provided by the coupling gaps 59, 59a, 59b, between adjacent resonators. In this particular case, the inter-resonator coupling strength is adjusted by changing the gap width between the adjacent resonators, as well as by shifting the resonator's location in the transverse direction for the fine adjustment. The input coupling circuit is in the inserted line form, which comprises an input line 55 with its extended line 56 inserted into the split spiral line of the first resonator 53 with a coupling gap 57 between them. The output coupling circuit is in the inserted line form, which comprises an output line 55a with its extended line 56a inserted into the split spiral line of the last resonator 53a with a coupling gap 57a between them. Gold connecting pads 58 and 58a are disposed on the input and output lines 55 and 55a, respectively, providing the connections to the mini-filter's input and output connectors 58b and 58c, respectively, shown in Figs. 5a and 5c.

Fig. 6 shows a fourth embodiment of the 4-pole HTS mini-filter circuit having four self-resonant circular spiral resonators as its frequency selecting element, in which Fig. 6a shows the circuit top or front view with the lid of the case removed, Fig. 6b shows the end view, and Fig. 6c shows the side view. Numeral 60 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on the front side of the substrate 60 as shown in Figs. 6a~6c. As indicated by the end view shown in Fig. 6b and the side view shown in Fig. 6c, the back side of the substrate 60 is disposed with a blank HTS film 61 serving as the ground of the mini-filter circuit, and a gold film 62 is disposed on top of blank HTS film 61 serving as the contact to the mini-filter's case 62a, shown in Figs.

6a~6c. The case lid 62b is shown in Figs. 6b and 6c. In Fig. 6a, numerals 63, 64, 63a, and 64a are the four self-resonant circular spiral resonators. The inter-resonator couplings are provided by the coupling gaps 63b, 63c, 63d, between adjacent resonators. The input coupling circuit is in the parallel line form, which comprises an input line 66 and an extended line 67, the input coupling is provided by the gap 69 between 67 and the first resonator 63. The output coupling circuit is in the parallel line form, which comprises an output line 66a and an extended line 67a, the output coupling is provided by the gap 69a between 67 and the first resonator 63. Two tuning pads 65, 65a are placed at the center of resonators 63 and 63a, respectively, for fine tuning the resonant frequency of the resonators 63 and 63a. Gold connecting pads 68 and 68a are disposed on the input and output lines 66 and 66a, respectively, providing the connections to the mini-filter's input and output connectors68b and 68c, respectively, shown in Figs. 6a and 6c.

A5 (continued)

Fig. 7 shows one embodiment of a 5-pole HTS mini-filter circuit having five self-resonant rectangular spiral resonators as its frequency selecting element, in which Fig. 7a shows the circuit top or front view with the lid of the case removed, Fig. 7b shows the end view, and Fig. 7c shows the side view. Numeral 70 is a dielectric substrate with a front side and a back side. The HTS mini-filter circuit is disposed on the front side of the substrate 70 as shown in Figs. 7a~7c. As indicated by the end view shown in Fig. 7b and the side view shown in Fig. 7c, the back side of the substrate 70 is disposed with a blank HTS film 71 serving as the ground of the mini-filter circuit, and a gold film 72 is disposed on top of blank HTS film 71 serving as the contact to the mini-filter's case 72a, shown in Figs. 7a~7c. The case lid 72b is shown in Figs. 7b and 7c. In Fig. 7a, numerals 73, 74, 73a, and 74a are the four self-resonant rectangular single spiral resonators, numeral 75 is a self-resonant rectangular double spiral resonator, which is centrally located and thus serves as the middle resonator. The use of double spiral resonator 75 at the middle of the 5-pole filter is to make the circuit geometry symmetrical with respect to the input and the output. This approach is also suitable for any symmetrical

mini-filter with odd number poles. The inter-resonator couplings are provided by the coupling gaps 75a, 75b, 75c, 75d, between adjacent resonators. In this particular case, the inter-resonator coupling strength is adjusted by changing the gap width between the adjacent resonators. The input coupling circuit is in an inserted line form, which comprises an input line 76 with its extended narrower line 77 inserted into the split spiral line of first resonator 73 with a coupling gap 78 between them. The output coupling circuit is in a inserted line form, which comprises an output line 76a with its extended narrower line 77a inserted into the split spiral line of last resonator 73a with a coupling gap 78a between them. Gold connecting pads 79 and 79a are disposed on the input and output lines 76 and 76a, respectively, providing the connections to the mini-filter's input and output connectors 79b and 79c, respectively, shown in Figs. 7a and 7c.

75 (continued)

Fig. 8 shows a 2-channel mini-multiplexer, each channel has a 8-pole HTS mini-filter 83, 83a (see Fig. 8a), respectively, with eight rectangular self-resonant spiral resonators. Fig. 8a shows the top or front view with the lid of the case removed, Fig. 8b shows the end view, and Fig. 8c shows the side view. Numeral 80 is a dielectric substrate with a front side and a back side. The HTS mini-multiplexer circuit is disposed on the front side of substrate 80 as shown in Figs. 8a~8c. As indicated by the end view shown in Fig. 8b and the side view shown in Fig. 8c, the back side of the substrate 80 is disposed with a blank HTS film 81 serving as the ground of the mini-multiplexer circuit, and a gold film 82 is disposed on top of blank HTS film 81 serving as the contact to the mini-multiplexer's case 82a, shown in Figs. 8a~8c. The case lid 82b is shown in Figs. 8b and 8c. The frequency bands of mini-filters 83 and 83a are slightly different and without overlapping to form two channels. As shown in Fig. 8a, the input coupling circuits of mini-filters 83 and 83a are in the parallel lines form, which comprise input lines 84 and 84a and the gaps 84b, 84c, respectively, between input lines 84 and 84a and the first spiral resonator of filters 83 and 83a, respectively. A distribution network in a single binary splitter form serves as the input of the multiplexer, which comprises the common input line 86, a T-junction

87, and branch lines 85 and 85a, with one end of each of the branch lines 85 and 85a commonly connected to T-junction 87, and the other end thereof connected to coupling lines 84 and 84a, respectively. The dimensions of coupling lines 84 and 84a, branch lines 85 and 85a, common input line 86 and T-junction 87 are selected in such a way to provide the input impedance matching of the mini-multiplexer over the frequency range covering the two frequency bands of filters 83 and 83a. The output coupling circuits of filters 83 and 83a are in the parallel lines form, which comprise the output lines 87a and 87b, and the gap 87c, 87d, respectively, between them and the last resonator of filters 83 or 83a. Output lines 87a and 87b also serve as the output lines for the two channels of the mini-multiplexer. Gold connecting pads 88, 88a and 88b are disposed on the input line 86, and output lines 87a and 87b, respectively, providing the connections to the mini-multiplexer'sinput connector 89 and the two output connectors 89a and 89b, shown in Figure 8a.

A5 (continued)

It should be understood that the form of the self-resonant spiral resonators in the mini-multiplexer is not restricted to the rectangular form illustrated in Fig. 8, but rather they can be of any configuration such as shown in Figs. 2a-2d or combinations thereof. Further it is to be understood that the form of the input and output coupling circuits of the mini-filters in the mini-multiplexer is not restricted to the parallel line form shown in Fig. 8, but instead other line forms may be used, such as the inserted line form or combinations of inserted line form and parallel line form.

Fig. 9 shows a second embodiment of the 4-channel mini-multiplexer, each channel having an 8-pole HTS mini-filter with eight self-resonant rectangular spiral resonators, in which Fig. 9a shows the top or front view with the lid of the case removed, Fig. 9b shows the end view, and Fig. 9c shows the side view. Numeral 90 is a dielectric substrate with a front side and a back side. The HTS mini-multiplexer circuit is disposed on the front side of substrate 90 as shown in Figs. 9a~9c. As indicated by the end view shown in Fig. 9b and the side view shown in Fig. 9c, the back side of the substrate 90 is

disposed with a blank HTS film 91 serving as the ground of the mini-multiplexer circuit, and a gold film 92 is disposed on top of blank HTS film 91 serving as the contact to the mini-multiplexers case 98 shown in Figs. 9a~9c. The case lid 99 is shown in Figs. 9b and 9c. In Fig. 9a, numerals 93 and 93a are used to designate two 2-channel mini-multiplexers similar to that shown in Fig. 8. The frequency bands of mini-multiplexers 93 and 93a are slightly different and without overlapping. As shown in Fig. 9a, the distribution network at the input of the 4-channel mini-multiplexer is in a 2-stage cascaded binary splitter form. The first stage comprises a common input line 95, a T-junction 96 and two branch lines 94 and 94a, with one end of each of the branch lines 94 and 94a commonly connected to T-junction 96, and the other end thereof connected to the input lines 94b and 94c, respectively, of the second stage. The second stage comprises two binary splitters, which actually are the input binary splitters of the two 2-channel mini-multiplexers 93 and 93a, and comprise input lines 94b and 94c; T-junctions 94d and 94e; branch lines 94f, 94g, 94h and 94i; and input lines 94j, 94k, 94l and 94m, as shown in Fig. 9a. The dimensions of mini-multiplexers 93 and 93a, branch lines 94 and 94a, input lines 94b and 94c, T-junctions 94d and 94e, branch lines 94f, 94g, 94h and 94i, input lines 94j, 94k, 94l and 94m, common input line 95 and T-junction 96 are selected in such a way to provide the input impedance matching of the mini-multiplexer over the frequency range covering the four frequency bands of the 4-channel mini-multiplexer. The output circuits of the 4-channel mini-multiplexer comprise the two 2-channel mini-multiplexers' output lines: 97, 97a, 97b, 97c, which serve as the four output lines for the 4-channel mini-multiplexer as shown in Fig. 9a.

15 (continued)

Fig. 10 shows a third embodiment of the 4-channel mini-multiplexer, each channel comprising an 8-pole HTS mini-filter 103, 103a, 103b, 103c (see Fig. 10a), with eight self-resonant rectangular spiral resonators. Fig. 10a shows the top or front view with the lid of the case removed, Fig. 10b shows the end view, and Fig. 10c shows the side view. Numeral 100 is a dielectric substrate with a front side and a back side. The HTS mini-multiplexer circuit is disposed on the

15 (continued)

front side of substrate 100 as shown in Figs. 10a~10c. As indicated by the end view shown in Fig. 10b and the side view shown in Fig. 10c, the back side of the substrate 100 is disposed with a blank HTS film 101 serving as the ground of the mini-multiplexer circuit, and a gold film 102 is disposed on top of blank HTS film 101 serving as the contact to the mini-multiplexer's case 109, shown in Figs. 10a~10c. The case lid 109a is shown in Figs. 10b and 10c. The frequency bands of filters 103, 103a, 103b, and 103c are slightly different and without overlapping to form four channels. As shown in Fig. 10a, the distribution network at the input of the 4-channel mini-multiplexer is in a matched branch lines form, which comprises a common input line 106, a matching section 105, line sections 104, 104a, 104b, 104c, and five junctions: 107, 107a, 107b, 107c and 107d. The dimensions of line sections 104, 104a, 104b and 104c, matching section 105, common input line 106, and junctions 107, 107a, 107b, 107c and 107d, are selected in such a way to provide the input impedance matching of the mini-multiplexer over the frequency range covering the four frequency bands of the 4-channel mini-multiplexer. The output circuits of the 4-channel mini-multiplexer comprise the four mini-filter's output lines: 108, 108a, 108b, 108c, which serve as the four output lines for the 4-channel mini-multiplexer as shown in Fig. 10a.

Fig. 11 shows an example of a 4-pole HTS filter in the strip line form with four rectangular self-resonant spiral resonators with rounded corners as its frequency selecting element. Fig. 11a is a side view of the filter and Fig. 11b is a view as seen along lines and arrows A-A of Fig. 11a. Numeral 110 is a dielectric substrate with a front side and a back side. The HTS filter circuit 113 is disposed on the front side of substrate 110 as seen in Fig. 11b. As shown in Fig. 11a, a first blank HTS film 111 is disposed on the back side of substrate 110 serving as one of the two ground planes for the strip line, a first gold film 112 is disposed on top of first blank HTS film 111 serving as the contact to the filter's case 118, shown in Figs. 11a and 11b. Numeral 110a is a dielectric superstrate with a front side and a back side. As shown in Fig. 11a, a second blank HTS film 111a is disposed on the

back side of superstrate 110a serving as one of the two ground planes for the strip line, a second gold film 112a is disposed on top of second blank HTS film 111a serving as the contact to the filter's case lid 119, shown in Fig. 11a. As is also shown in Fig. 11a, superstrate 110a is smaller in size than substrate 110, whereby the first end (e.g., microstrip line 115 and gold contact pad 116) of the input coupling circuit and the first end (e.g., microstrip line 115a and gold contact pad 116a) of the output coupling circuit are each located outside the dimensions of superstrate 110a, that is, they are not covered by superstrate 110a. Although not shown, it is understood that the mirror image of HTS filter circuit 113 could also be disposed on the front side of superstrate 110a and the two mirror image circuits aligned. As shown in Fig. 11b, the input and output strip lines 114 and 114a are extended into broader microstrip lines 115 and 115a, respectively, on the substrate 110. Gold contact pads 116 and 116a are disposed on microstrip lines 115 and 115a, respectively (also seen in Fig. 11a), providing the connections to the filter input and output connectors 117 and 117a , respectively, shown in Figs. 11a and 11b. The line width of output strip lines 114 and 114a, and microstrip lines 115 and 115a, are selected in such a way to achieve the impedance matching at the input and the output.

25 (continued)

In all of the embodiments described above, it is preferred that the high temperature superconductor is selected from the group consisting of $YBa_2Cu_3O_7$, $Tl_2Ba_2CaCu_2O_8$, $TlBa_2Ca_2Cu_3O_9$, $(TlPb)Sr_2CaCu_2O_7$ and $(TlPb)Sr_2Ca_2Cu_3O_9$. It is also preferred that the substrate and superstrate are independently selected from the group consisting of $LaAlO_3$, MgO, $LiNbO_3$, sapphire and quartz.

EXAMPLE

A mini-filter having the circuit layout shown in Figure 12 was prepared. It is a 3-pole 0.16 GHz bandwidth centered at 5.94 GHz mini filter in the microstrip line form. It consists of three rectangular self-resonant spiral resonators, 121, 121a, 121b, each having a tuning pad at the center, 122, 122a, 122b, parallel lines input and output coupling circuits, 123, 123a. The substrate 120 is made of $LaAlO_3$

with dimensions of 5.250 mm x 3.000 mm x 0.508 mm. The HTS thin film is $Tl_2Ba_2CaCu_2O_8$. The filter was fabricated, and tested at 77 K. The measured S-parameter data are shown in Fig. 13, in which Fig. 13a shows S_{11} versus frequency data, Fig. 13b shows S_{12} versus frequency data, Fig. 13c shows S_{21} versus frequency data, Fig. 13d shows S_{22} versus frequency data. S_{11} is the magnitude of the reflection coefficient from the input port; S_{21} is the magnitude of the transmitting coefficient from the input port to the output port; S_{22} is the magnitude of the reflection coefficient from the output port; and S_{12} is the magnitude of the transmitting coefficient from the output port to the input port. The results show that the center frequency is about 5.95 GHz and the band width is about 170 MHz. The return loss is about 12 dB (see, e.g., Fig. 13a, wherein the scale along the ordinate axis is 5 dB per division). Reference to Fig. 13b or 13c shows there is essentially zero insertion loss. The measured data were in agreement with the computer simulated data very well, the center frequency difference was less than 0.1%.

A5 (continued)

The mini-filter was also tested under two different conditions. That is, it was tested in the air with a relative dielectric constant of approximately 1.00, and also was tested in liquid nitrogen with a relative dielectric constant of approximately 1.46. Fig. 14 shows the S_{21} versus frequency data, in which 131 is for the air data and 132 is for the liquid nitrogen data. The results indicate a frequency shift of only 0.04 GHz corresponding to 0.67% of the center frequency. The very small frequency shift is an indirect indication of most electromagnetic fields confinement beneath the spiral resonators.

The filter was also tested under power from 0.01 watt up to 0.2 watt cw rf power without measurable changes in its S_{21}. The Third Order Intercept (TOI) test is an indication of the non-linearity of the filter. The higher the intercept, the higher the power handling capability of the filter. Test data are shown in Fig. 15 in a log-log scale, in which line 141 is the best fit straight line with a slope of 1 for the sum of two fundamental frequencies, line 142 is the best fit straight line with a slope of 3 for the third order intermadulation. The

a5 (concluded)

intercept of these two lines gives a TOI of 39.5 dBm, which is a high value and indicates the power handling capability of the filter. Both the power and the TOI test data are in line with similar conventional HTS filters with the same line width and ten times larger size. These test results confirmed that the one order of magnitude reduction of size does not degrade the mini-filter's performance compared to the conventional design.

Appendix C
Marked-Up Version
(Showing Amendments to)
Claims 1, 3, 5, 10~13 and 16

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1. (once amended) A high temperature superconductor mini-filter comprising:

(a) a substrate having a front side and a back side;

(b) at least two self-resonant spiral resonators in intimate contact with the front side of the substrate, each of said resonators independently comprising a high temperature superconductor line oriented in a spiral fashion (i) such that adjacent lines are spaced from each other by a gap distance which is less than the line width; and (ii) so as to ~~form~~ provide a central opening within the spiral resonator, the dimensions of which are approximately equal to the gap distance;

(c) at least one inter-resonator coupling;

(d) an input coupling circuit comprising a transmission line with a first end thereof connected to an input connector of the filter and a second end thereof coupled to a first one of the at least two self-resonant spiral resonators;

(e) an output coupling circuit comprising a transmission line with a first end thereof connected to an output connector of the filter and a second end thereof coupled to a last one of the at least two self-resonant spiral resonators;

(f) a blank high temperature superconductor film disposed on the back side of the substrate as a ground plane;

(g) a conductive film disposed on the blank high temperature superconductor film as the contact to a case for said mini-filter;

(h) a superstrate having a front side and a back side, wherein the front side of the superstrate is positioned in intimate contact with the at least two resonators disposed on the front side of the substrate;

(i) a second blank high temperature superconductor film disposed at the back side of the superstrate as a ground plane; and

(j) a second conductive film disposed on the surface of said second high temperature superconductor film as a contact to ~~a~~said case for said mini-filter

wherein the superstrate is smaller in size than the substrate; and wherein the first end of the input coupling circuit and the first end of the output coupling circuit are each located outside the dimensions of the superstrate.

3. (once amended) A high temperature superconductor mini-multiplexer comprising:

(a) at least two mini-filters, each mini-filter having a frequency band which is different from and does not overlap with the frequency bands of each other mini-filter;

(b) a distribution network with one common port as an input for the mini-multiplexer and multiple distributing ports, wherein ~~one~~a respective distributing port is connected to an input of a corresponding ~~input of one~~ mini-filter; and

(c) a multiple of output lines, wherein ~~one~~ a respective output line is connected to an output of a corresponding ~~output of one~~ mini-filter;

wherein each of said at least two mini-filters comprises:

(d) a substrate having a front side and a back side;

(e) at least two self-resonant spiral resonators in intimate contact with the front side of the substrate, each of said resonators independently comprising a high temperature superconductor line oriented in a spiral fashion (i) such that adjacent lines are spaced from each other by a gap

distance which is less than the line width; and (ii) so as to ~~form~~ provide a central opening within the spiral resonator, the dimensions of which are approximately equal to the gap distance;

(f) at least one inter-resonator coupling;

(g) an input coupling circuit comprising a transmission line with a first end thereof connected to ~~an input connector of the filter~~ said respective distributing port and a second end thereof coupled to a first one of the at least two self-resonant spiral resonators;

(h) an output coupling circuit comprising a transmission line with a first end thereof connected to ~~an output connector of the filter~~ said respective output line and a second end thereof coupled to a last one of the at least two self-resonant spiral resonators;

(i) a blank high temperature superconductor film disposed on the back side of the substrate as a ground plane; and

(j) a conductive film disposed on the blank high temperature superconductor film as the contact to a case for said mini-filter.

5. (once amended) The mini-multiplexer of Claim 3 wherein a respective conductive tuning pad is disposed in the central opening of one or more of said self-resonant spiral resonators.

10. (once amended) The mini-multiplexer of Claim 3 wherein all said self-resonant spiral resonators have an identical configuration selected from the group consisting of rectangles, rectangles with rounded corners, polygons and circles.

11. (once amended) The mini-multiplexer of Claim 3 wherein the input and output coupling circuits are in the parallel lines form and each comprises:

(a) a microstrip line,
(b) a gap between ~~the~~ each said microstrip line and the first resonator for the input coupling circuit, or the last resonator for the output coupling circuit, of the said mini-filter, and
(c) a gold pad at the end the microstrip line.

12. (once amended) The mini-multiplexer of Claim 3 wherein one or more of said mini-filters further comprises:

(k) a superstrate having a front side and a back side, wherein the front side of the superstrate is positioned in intimate contact with the at least two resonators disposed on the front side of the substrate;
(l) a second blank high temperature superconductor film disposed at the back side of the superstrate as a ground plane; and
(m) a second conductive film disposed on the surface of said second high temperature superconductor film as a contact to said case for said mini-filter.

13. (once amended) The mini-multiplexer of Claim 12 wherein the respective superstrate is smaller in size than the corresponding substrate; and wherein the first end of the input coupling circuit and the first end of the output coupling circuit are each located outside the dimensions of the corresponding superstrate.

16. (once amended) The mini-multiplexer of Claim 12 wherein a respective conductive tuning pad is disposed in the central opening of one or more of said self-resonant spiral resonators.